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The impact of different mobile phone tasks on gait behaviour in healthy young adults

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ABSTRACT

Introduction: The aim of this study was to examine the impact of different mobile phone tasks on gait behaviour in healthy young adults.
Methods: An experimental design was used in this study. Twenty-five participants, 7 males and 18 females, aged 22.56 ± 2.45 years completed 5 tasks whilst walking. The conditions consisted of no task, calling, playing a game, listening to music, texting, and watching a video. Gait behaviour was captured using a Zebris Force Distribution Measurement (FDM) system, and 6 trials were recorded under each condition. Temporo-spatial gait variables included step length, step time, stride length, stride time, step width, cadence, velocity, foot rotation angle, % stance phase, % loading response, % single support time, % pre-swing, % swing phase, and % double support time. In addition, the level of confidence during walking was assessed using an 11 point scale.
Results: Repeated measure ANOVAs with post hoc pairwise comparisons revealed that mobile phone usage altered all temporo-spatial variables significantly ($p < 0.05$), except for foot rotation angle. Texting and watching a video were the most notable changes, with listening to music showing no difference when compared to no task.
Conclusion: Mobile phone usage modified gait behaviour to such a degree that it may compromise safety by dividing an individual's attention, with the lowest level of confidence being while watching video and texting. Although the potential danger of the use of mobile phones while walking is being discussed worldwide, a clear policy still does not exist, and individuals using mobile phones, in particular for watching video and texting while walking, should be made more aware of the risk of injury.

1. Introduction

Currently, mobile phones are frequently used for many purposes such as calling, sending messages, receiving news, and entertainment (Thornton et al., 2014). Due to its convenience, this usage has become popular, even when performing daily activities. A

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time-trend analysis has demonstrated that the utilization of mobile phones has increased substantially from 2011 to 2017, especially in children and teenagers, and these are frequently used while engaging in other leisure activities (Auhuber et al., 2019).

Pedestrians and drivers are at a greater risk of injury when using mobile phones whilst crossing the street and driving, which is supported by data of the US Consumer Product Safety Commission on injuries recorded from hospitals between 2004-2010. It was reported that mobile-phone related injuries among pedestrians were greater relative to the total number of pedestrian injuries. This injury rate was parallelled to the increase of injuries for drivers. Pedestrian injuries related to mobile phone usage were higher for males and individuals under the age of 31 (Nasar and Troyer, 2013), however, this study did not distinguish the type of pedestrian injuries. Another study relied on the National Electronic Injury Surveillance System data from the US between 2000-2011, reported that 5754 emergency cases were caused by mobile phone usage, of which these injuries, 78% were associated with falling, with the incidence increasing year on year (Smith et al., 2013). Definitions and utilization of terminology are crucial and have been recommended for the appropriate injury classification in order to obtain clear information for formulating health promotion and prevention policies in road safety (Methorst et al., 2017a, 2017b). A review conducted by Schepers et al. (2017) reported that older women had a higher pedestrian fall risk. Surprisingly, victims of outdoor falls had good general health and had similar balance scores to those who did not experience a fall (Schepers et al., 2017). A study of 14,221 middle school students demonstrated that the prevalence of road traffic injuries, pedestrian collisions, and falls were 4.9, 16.2, and 10.1%, respectively. Furthermore, the problematic mobile phone use was associated with road traffic injuries (adjusted Odd Ratio (OR) = 3.93, 95% Confident Interval (CI) = 3.01–5.12), pedestrian collisions (OR = 3.56, 95% CI = 3.05–4.15), and falls (OR = 3.91, 95% CI = 3.25–4.71) (Tao et al., 2016).

Interactive, immersive or semi-immersive virtual environment settings have all been used to investigate the effect of mobile phones by replicating a situation closest to the actual environment. Such work has reported that talking on mobile phones distracted pedestrians considerably and has a negative impact on all variables associated with pedestrian safety (Stavrinos et al., 2011). In addition, Schwebel et al. (2012) investigated mobile phone usage in 138 college students when crossing a street in a virtual environment. Pedestrians who were distracted by music listening or texting tended to be hit by vehicles more than the undistracted groups (Schwebel et al., 2012). This is supported by the findings from Banducci et al. (2016) who showed that pedestrians took a longer time to initiate crossing and had a head orientation toward the mobile phone screen, reducing their field of view as well as distracting them (Banducci et al., 2016).

Previous studies have been conducted on the modification of gait during mobile phone usage but these predominantly considered talking, reading, and texting. Lamberg and Muratori (2012) used a simple method of recording duration and final location of the heel during walking over an 8-m walkway with and without vision being occluded whilst talking and texting on a mobile phone. Linear distance travelled, lateral angular deviation from the initiation line, and gait speed were extracted. They found that healthy young adults had significant reductions in gait speed when talking and texting compared to walking with no distraction. In addition, texting increased the lateral deviation and the linear distance travelled (Lamberg and Muratori, 2012). A more detailed analysis using three-dimensional motion analysis was investigated by Schabrun et al. (2014) and Parr et al. (2014). Schabrun et al. (2014) showed that when walking whilst texting and reading, healthy adults walked with a slower speed, head in a flexed position, greater absolute lateral foot placement position, greater in-phase motion of the thorax and head in all planes of motion, and less motion between the thorax and head (Schabrun et al., 2014). Whereas, Parr et al. (2014) showed an increase in step width and double support time (DST) and decreases in toe clearance, step length, and cadence (Parr et al., 2014). Lim et al. (2015) investigated the effect of texting during walking on vision and gait performance in healthy volunteers (Lim et al., 2015). They found that half of the visual cues were not perceived when walking while texting, with no differences in temporal and spatial gait parameters, however, they did observe a greater total medio-lateral excursion of the pelvis whilst texting.

Factors such as speed and age have also been explored during dual-gait tasks while using mobile phones. Crowley et al. (2019) studied the effects of mobile phone distractions on gait performance and found that this was not significantly different when performed at fast and comfortable gait speeds. However, walking while texting produced a significant decrease in gait speed, stride length, and cadence and a significant increase in DST at both gait speeds. Texting also increased the relative variability during walking, which was observed by a significant increase in the coefficient of variation for cadence, stride length, and DST (Crowley et al., 2019). When confronted with obstacles, mobile phone users have been shown to be able to modify visual search behaviour by looking less frequently and having a safe gait manner by slowing their speed and using a cautious stepping strategy (Timmis et al., 2017). From a comparative study of gait deviation when distracting vision and attention using mobile phones in elders and young adults, greater changes of gait variables have been reported in the elders (Prupetkaew et al., 2019). The changes in these gait variables possibly leading to an increase in the risk of falls or loss of stability, which is present even in young adults (Caramia et al., 2017; Lim et al., 2015; Parr et al., 2014).

During locomotion, people may or may not be able to preserve the ability to walk properly whilst using mobile phones. Success or failure to adapt the motions may be explained by the Wickens' Multiple-Resource Theory (MRT) (Wickens, 2002). This describes the particular structural dimensions of human information processing which can account for variance in time-sharing performance. The impact of this theory is usually used to support the predictions regarding the ability of human performance in high workload multi-task environments. In particular, mobile phone functions have increased and now include; watching videos, playing games, listening to music, typing messages, talking, taking pictures, taking videos, etc. However, only a few studies have compared gait alterations during the range of mobile phones usage. Changes in temporo-spatial gait variables during the different mobile phone tasks may provide useful information on the possible risks related to walking while using mobile phones. Therefore, this study aimed to compare the effect of a range of mobile phone tasks on temporo-spatial gait variables during walking. We hypothesized that gait variables would be different among the mobile phone tasks.

2. Materials and methods

2.1. Study design

This was an experimental design which compared the temporo-spatial variables during walking when using a mobile phone under different conditions. The protocol was approved by the Institutional Review Board (COA no. MU-CIRB 2019/015.2501). All participants were informed about the procedure and signed a consent form prior to participation in the study.

2.2. Participants

Twenty-five healthy young adult volunteers were recruited using convenience sampling from a Thai University student population. Participants were recruited if they were healthy men or women age between 18 to 25 years, who regularly used mobile phones to perform tasks such as calling, typing, watching videos, listening to music, and playing games, averaging approximately 2 h per day. They were excluded if they had difficulty walking, visual deficit that could not be corrected by glasses or contact lenses, history of musculoskeletal or neurological diseases that affect gait or posture, had symptoms of vertigo or dizziness on the day of assessment, leg length discrepancy more than 1 cm, or consumed alcoholic beverages within 24 h before participation.

2.3. Procedure

To compare the temporo-spatial gait variables during walking under different mobile phone tasks, the study used the Zebris Force Distribution Measurement (FDM) system, which comprised of a platform $307 \times 60.5 \times 2.1$ cm (Allgäu, Germany), and has been shown to be valid and reliable to measure the temporo-spatial gait parameters and used as a gold standard for other simpler gait measurements (Aung et al., 2020). The instrument was set up within the Physical Therapy Clinic, Faculty of Physical Therapy, Mahidol University, Bangkok, Thailand (Fig. 1). Participants practised walking on the platform for 1–2 trials until they were comfortable with the testing environment and using a mobile phone prepared by the researcher for data collection. Participants walked with bare feet at a self-selected comfortable speed. Gait data were captured at a sampling rate of 100 Hz, and 6 trials were collected under each testing condition. Data collection started with the baseline condition of no mobile phone use, and the remaining five mobile phone conditions were randomly generated by a mobile phone application (Random Tools, version 3.4.1, Thi Vo, Vietnam). A 5-min break was allowed between testing conditions. Details of the testing conditions are presented in Table 1. After all testing conditions were completed, participants were asked to rate their confidence in walking using a 10-point numeric scale from “0” no confidence to “10” fully confident.

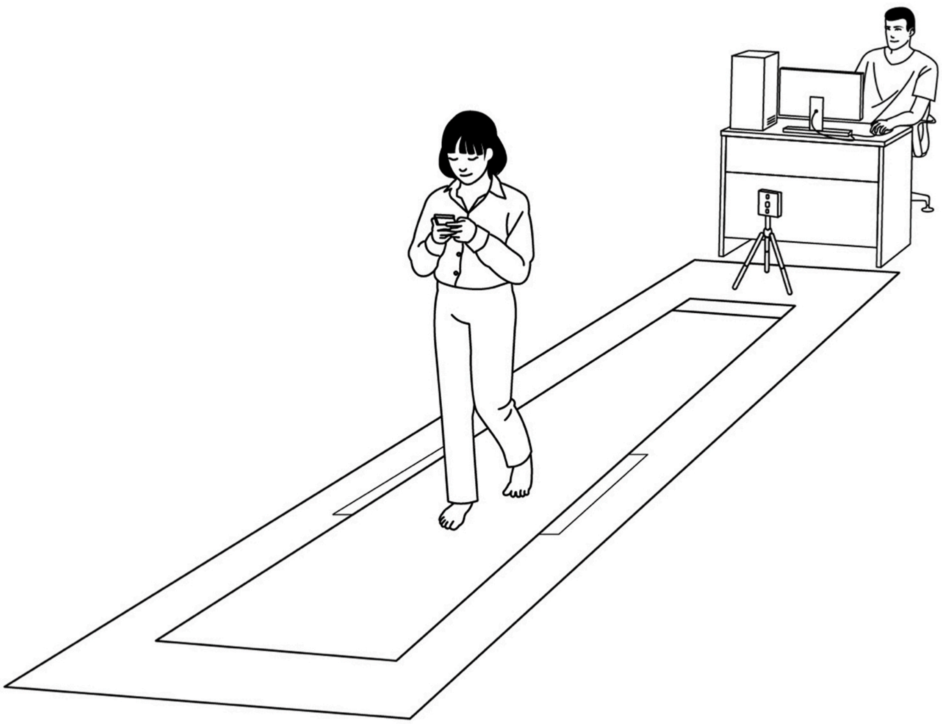

Fig. 1. Data collection scenario and set up.

2.4. Data processing

Temporo-spatial gait variables included step length, step time, stride length, stride time, step width, cadence, velocity, foot rotation angle, % stance phase, % loading response, % single support time (SST), % pre-swing, % swing phase, and % double support time (DST), which were computed using the Zebris WinFDM Software version 0.1.11 (Zebris Medical GmbH, Germany). Six trials were averaged under each condition, and data were selected from the middle part of the walkway to reduce acceleration and deceleration effects. The Kolmogorov Smirnov Goodness of Fit test was used to test the data distribution, and all data were found to be normally distributed. Repeated measure ANOVAs with Bonferroni post hoc Pairwise comparisons were used to explore the differences between the test conditions. All analyses were performed using SPSS software version 20.0 (IBM corp, USA) and the significance level was set at $p < 0.05$.

The sample size was estimated using pilot data from 10 subjects using gait speed and step length, and using the G*Power program version 3.1.9.2, using a within factors analysis and an alpha error of 0.05 and 80% power. A sample of 25 participants was considered suitable to explore the research question.

3. Results

The characteristics of the participants and details relating to mobile phone use are shown in Table 2. The majority of the participants regularly used mobile phones for texting, watching movies, reading internet content, calling, and listening to music.

Table 3 presents the comparison of temporo-spatial gait variables and the level of confidence in walking across different mobile phone tasks. Significant differences ($p < 0.05$) were seen across all testing variables, except for the foot rotation angle ($p > 0.05$). Table 4 shows the pairwise comparisons, the greatest step length and stride length were found in the baseline condition, followed by listening, calling, playing, watching, and texting, respectively. There was an increase in step time and stride time during the conditions of calling, playing, texting, and watching compared to baseline and listening. In addition, stance phase, loading response, pre-swing, and total DST all showed an increase in duration, and a shorter duration in SST and swing time when playing, texting, and watching when compared to the other conditions. Step width was greatest when playing and watching, which decreased when texting, calling, listening, and was narrowest in the baseline condition. Cadence did not vary much between conditions, with the exception of listening which showed the greatest step frequency per minute. The maximum velocity was also found in listening, followed by the baseline. The pairwise comparison demonstrated that almost all temporo-spatial variables were different between the conditions, except for the conditions of baseline and listening, calling and texting, and texting and watching which showed no difference in all gait variables. In addition, the level of confidence in walking during the different mobile phone tasks showed the greatest confidence during baseline, followed by listening, playing, and a significantly decreased confidence during watching and the least confidence during texting.

4. Discussion

The results from the present study on the use of mobile phone applications concurrent with walking were in agreement with previous studies (Caramia et al., 2017; Crowley et al., 2019; Magnani et al., 2017; Niederer et al., 2018; Prupetkaew et al., 2019; Tian et al., 2018). This confirmed the hypothesis that walking while using mobile phones could affect the temporo-spatial gait variables even in healthy young adults. Mobile phone usage made the participants walked with shorter step and stride lengths, longer step and stride times, slower gait speed, longer periods of stance phase, loading response, pre-swing, and DST but with shorter periods of SST and swing time. Widening of step width and increased cadence were also presented when using a mobile phone.

When considering the changes in various temporo-spatial gait variables that inferred by different tasks. It was found that texting and watching were the most alterations, detecting by gait variables. It is evident that humans can divide attention between visual and auditory better than between two visual channels. Texting and watching used two aspects of visual processing; focal and ambient visions, to define separate resources for supporting efficient time-sharing. The focal vision is required in reading on a small object, while the ambient vision involves peripheral vision. The latter is used for sensing orientation related to the environment (Wickens, 2002). In many studies, it was found that texting was the task causing significant changes in gait variables and increased the amount of gait variability (Caramia et al., 2017; Crowley et al., 2019; Tian et al., 2018). There was also a report of the increased gait variability

Table 1
Details of the testing conditions.

Conditions	Details
1. Baseline	Participants walked at their self-selected speed without using the mobile phone.
2. Calling (Talking)	Participants walked and held a mobile phone in hand and talking to the researcher, where they had to answer set questions.
3. Playing a game (Playing)	Participants walked while playing the Piano Tiles game using both hands. The difficulty level of the game was set to the "easy level".
4. Listening to music (Listening)	Participants walked while listening to pop music using headphones with the mobile phone in a pocket. To ensure the participants listened to the music carefully, they were asked questions about the music after each trial was completed.
5. Texting messages (Texting)	Participants walked while typing short messages on the mobile phone. Participants were asked to type as accurately and as fast as possible. To control the difficulty level messages were prepared which contained 10 syllables, these were memorised and typed using a standardised keyboard and language.
6. Watching a video (Watching)	Participants walked while watching prepared video clips on the mobile phone. To ensure the participants paid attention to the videos, they had to answer questions about details in the videos after each trial.

Table 2
Participants characteristics and phone use.

Details	Values
Gender	n (%)
Male/Female	7 (28)/18 (72)
	Mean (sd)
Age (years)	22.56 (2.45)
Weight (kg)	58.20 (15.31)
Height (cm)	164.88 (0.83)
Leg length (cm) Right/Left	85.40 (5.02)/85.40 (5.08)
Number of years using a mobile phone	8.64 (2.34)
Brand of a current mobile phone	n (%)
Iphone	13 (52)
Samsung	7 (28)
Others	5 (20)
Normal daily phone use (hours)	n (%)
0-4	6 (24)
5-9	15 (60)
10 or more	4 (16)

and regularity when talking on a mobile phone (Magnani et al., 2017). However, this may vary between studies due to the different details of tasks being test. For example, Caramia et al. (2017) found that playing a math game caused significant changes in stride frequency, step time, step length, gait speed, and stride frequency (Caramia et al., 2017).

No changes in any gait variables when listening to music compared to the baseline were seen in this study. This corresponded with previous researchers (Magnani et al., 2017) who investigated the effect of mobile phones usage on gait in 20 young participants and found that gait variability and regularity were increased when calling, but there was no change in the listening condition. The maintenance of gait variables during listening to music in this study may be due to the type of music selected. The pop music used in this study had a moderate speed of rhythm, resulting in all gait variables being similar to those in the baseline condition. However, the number of beats per minute and personal preference to music could influence walking cadence, and may explain that listening produced the greatest cadence among all the test conditions.

Individuals were able to exploit the parallel processing of the multiple resources of focal and ambient visions (Wickens, 2002), as demonstrated by the successful use of a mobile phone while walking in this study. However, some mobile phone tasks may be sufficiently distracting and may lead to deficits in task-performance (Thornton et al., 2014). A secondary task that requires higher continuous visual processing was more likely to impair gait performance (Francis et al., 2015). The availability of visual information constitutes a critical control input during bipedal gait (Matthis et al., 2015). It has been shown that individuals are unable to perceive nearly 50% of visual cues during walking while texting when compared to normal visual conditions (Lim et al., 2015). Diminished vision and awareness when texting, talking, and reading on a mobile phone may pose an additional risk to falls, trips, and safety for pedestrians crossing the street or navigating obstacles (Banducci et al., 2016; Crowley et al., 2019; Schabrun et al., 2014). Traffic lights that regulate pedestrians when crossing a road in many countries are programmed at a standard walking speed of 1.2 m/s or 4.32 km/h (Webb et al., 2017). When considering walking speed, it was found that women and elderly individuals have slower speeds than this value (Bohannon, 1997), therefore, road crossing regulations define pedestrian walking speeds as fast as possible. Our study, found the speed of walking while using a mobile phone to text or watch a video was reduced to 3.50 and 3.51 km/h, which would likely cause a greater chance of injury during road crossing.

As the difference in sharing processing through various multiple sensory resources and the responses to specific mobile phone tasks, this can be observed by the changes in the different gait variables and demonstrated the different modifications in response to the different secondary mobile phone tasks. The findings can be related to the changes in gait and risk of fall in people with cognitive decline, which has previously shown that a decrease of gait speed of 10 cm/s (0.36 km/h) may be associated with severe injurious falls incidence, with an adjusted hazard ratio of 4.62 (Pieruccini-Faria et al., 2020). This would indicate that the change in gait speed during texting compared to the baseline of 0.56 km/h may help in the confirmation of potential risk when using mobile phone for texting, although the population between these studies is different.

Besides the multiple-resource sharing process, restriction of the arm swing motion is another reason that can affect gait characteristics. Holding a mobile phone in the hand during calling, playing, and texting may reduce the arm swing. This movement can affect the torso and leg movements, which may explain the reduction of step length. Another variable relating to postural control and balance in this study was step width, which was significantly increased during playing a game and watching the video when compared to the baseline. Due to the participants need to focus on the screen, they need to adjust by increasing step width or increasing base of support to increase stability. However, when considering texting, step width was not significantly different when compared to the baseline, this may be the result of the familiarity with texting as young adults frequently perform this task on mobile phones during walking.

The findings from this study suggest an order of conditions that affect walking ability from the most to the least, these were; watching, texting, playing, calling, and listening, respectively. When watching the video while walking, this affected vision and cognition, as participants had to remember details in the video to answer questions at the end of each testing trial. Also, texting affected both vision and cognition as participants had to remember the message before typing the sentence whilst walking. In the condition of playing, the vision was primarily affected, however, this did not interfere with cognition much as the style of the game did not require

Table 3
Comparison of the temporo-spatial gait variables among different tasks of mobile phone application.

Variables	Conditions						F	df	error	p-value*
	Baseline (1)	Calling (2)	Playing (3)	Listening (4)	Texting (5)	Watching (6)				
Step length (cm)	60.93 ± 4.55	57.96 ± 4.55	56.05 ± 6.06	60.17 ± 4.96	53.48 ± 6.15	54.17 ± 5.81	35.814	5	120	**<0.001**
Foot rotation (degree)	9.26 ± 3.29	10.27 ± 4.33	9.54 ± 4.07	9.72 ± 4.14	9.84 ± 4.73	9.70 ± 4.27	0.949	2.420	58.092	0.407
Step time (s)	0.54 ± 0.03	0.55 ± 0.04	0.55 ± 0.04	0.53 ± 0.03	0.56 ± 0.05	0.56 ± 0.06	5.258	2.602	62.440	**0.004**
Stance phase (%)	62.76 ± 1.03	62.97 ± 1.22	63.22 ± 1.32	62.75 ± 1.21	63.83 ± 1.67	63.90 ± 1.73	12.638	5	120	**<0.001**
Loading response (%)	12.77 ± 1.05	12.95 ± 1.15	13.25 ± 1.30	12.76 ± 1.21	13.87 ± 1.70	13.90 ± 1.74	12.977	3.237	77.681	**<0.001**
SST (%)	37.25 ± 1.13	37.06 ± 1.15	36.71 ± 1.23	37.24 ± 1.21	36.07 ± 1.73	36.06 ± 1.84	13.516	2.986	71.662	**<0.001**
Pre-swing (%)	12.74 ± 1.02	12.92 ± 1.17	13.24 ± 1.28	12.76 ± 1.21	13.88 ± 1.71	13.93 ± 1.80	13.959	3.073	73.742	**<0.001**
Swing phase (%)	37.24 ± 1.03	37.03 ± 1.22	36.78 ± 1.32	37.25 ± 1.21	36.17 ± 1.67	36.10 ± 1.73	12.638	5	120	**<0.001**
DST (%)	25.52 ± 2.06	25.86 ± 2.36	26.52 ± 2.55	25.56 ± 2.45	27.77 ± 3.41	27.87 ± 3.57	13.697	3.108	74.601	**<0.001**
Stride length (cm)	121.87 ± 9.08	115.90 ± 9.17	112.16 ± 12.15	120.38 ± 10.03	107.01 ± 12.32	108.41 ± 11.63	35.510	5	120	**<0.001**
Stride time (s)	1.09 ± 0.06	1.10 ± 0.09	1.10 ± 0.09	1.06 ± 0.07	1.12 ± 0.11	1.13 ± 0.12	5.507	2.622	62.921	**0.003**
Step width (cm)	8.90 ± 2.39	9.84 ± 2.66	10.44 ± 2.22	9.39 ± 2.30	9.94 ± 2.86	10.33 ± 2.48	4.197	2.648	63.560	**0.012**
Cadence (steps/min)	110.96 ± 5.80	109.79 ± 8.38	110.09 ± 8.40	113.83 ± 7.30	108.63 ± 10.43	107.44 ± 10.47	5.338	3.058	73.401	**0.002**
Velocity (km/h)	4.06 ± 0.40	3.82 ± 0.48	3.71 ± 0.57	4.11 ± 0.48	3.50 ± 0.65	3.51 ± 0.62	20.926	3.199	76.785	**<0.001**
Confidence level (0–10)	9.24 ± 1.27	8.72 ± 1.14	8.12 ± 1.51	8.88 ± 1.33	6.68 ± 1.49	6.88 ± 1.62	25.906	3.706	88.951	**<0.001**

Note: SST: Single support time, DST: Double support time.
*Significant difference tested by the repeated measure for ANOVA at $p < 0.05$.

Table 4
Pairwise comparison.

Variables	Pairwise comparisons (p-value)														
	1 vs 2	1 vs 3	1 vs 4	1 vs 5	1 vs 6	2 vs 3	2 vs 4	2 vs 5	2 vs 6	3 vs 4	3 vs 5	3 vs 6	4 vs 5	4 vs 6	5 vs 6
Step length (cm)	**0.001**	**<0.001**	1.000	**<0.001**	**<0.001**	0.300	**0.024**	**<0.001**	**0.004**	**<0.001**	**0.020**	0.050	**<0.001**	**<0.001**	1.000
Foot rotation (degree)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Step time (sec)	1.000	1.000	0.170	1.000	0.727	1.000	**0.026**	1.000	1.000	**0.042**	0.883	0.872	**0.009**	**0.030**	1.000
Stance phase (%)	1.000	0.180	1.000	**<0.001**	0.001	1.000	1.000	**0.018**	**0.046**	0.365	0.136	**0.030**	**<0.001**	**0.001**	1.000
Loading response (%)	1.000	0.171	1.000	**<0.001**	**0.003**	1.000	1.000	**0.013**	**0.039**	0.229	0.124	**0.043**	**<0.001**	**0.001**	1.000
SST (%)	1.000	0.066	1.000	**<0.001**	**0.004**	1.000	1.000	**0.010**	**0.047**	0.051	0.076	0.074	**<0.001**	**<0.001**	1.000
Pre-swing (%)	1.000	0.078	1.000	**<0.001**	**0.002**	1.000	1.000	**0.010**	**0.032**	0.161	0.073	**0.033**	**<0.001**	**<0.001**	1.000
Swing phase (%)	1.000	0.180	1.000	**<0.001**	**0.001**	1.000	1.000	**0.018**	**0.046**	0.365	0.136	**0.030**	**<0.001**	**0.001**	1.000
DST (%)	1.000	0.074	1.000	**<0.001**	**0.002**	1.000	1.000	**0.011**	**0.033**	0.173	0.093	**0.039**	**<0.001**	**<0.001**	1.000
Stride length (cm)	0.001	**<0.001**	1.000	**<0.001**	**<0.001**	0.340	**0.023**	**<0.001**	**0.005**	**<0.001**	**0.019**	**0.045**	**<0.001**	**<0.001**	1.000
Stride time (sec)	1.000	1.000	0.087	1.000	0.693	1.000	**0.024**	1.000	1.000	**0.031**	1.000	0.865	**0.009**	**0.024**	1.000
Step width (cm)	1.000	**<0.001**	1.000	0.094	**0.003**	1.000	1.000	1.000	1.000	**0.007**	1.000	1.000	1.000	**0.025**	1.000
Cadence (steps/min)	1.000	1.000	0.078	1.000	0.863	1.000	**0.026**	1.000	1.000	**0.041**	1.000	0.849	**0.021**	**0.011**	1.000
Velocity (km/h)	**0.012**	**0.002**	1.000	**<0.001**	**<0.001**	1.000	**0.003**	**0.022**	0.093	**<0.001**	0.117	0.096	**<0.001**	**<0.001**	1.000
Confidence level (0–10)	1.000	**0.004**	1.000	**<0.001**	**<0.001**	1.000	1.000	**<0.001**	**<0.001**	0.131	**0.006**	**0.014**	**<0.001**	**<0.001**	1.000

Note: SST: Single support time, DST: Double support time, vs: versus.
1: Baseline, 2: Calling, 3: Playing, 4: Listening, 5: Texting, 6: Watching.
*Pairwise comparisons tested by the Bonferroni post hoc at $p < 0.05$.

any planning. Calling was one of the easier tasks, as participants were able to look at the walkway and it was the most familiar task for young adults, and the conversation was a common topic that did not require calculation or memory. Listening can be considered as the easiest task that showed the same gait variables as in the baseline condition. These findings corresponded with the self-confidence rating scale by the participants, with the least confidence to perform mobile tasks being during texting and watching, with the most confidence during listening.

This study is limited as a non-realistic laboratory setting was used. Adding an interactive virtual environment may be used in future studies to obtain information on how gait behaviour is modified in a simulated environment, with a view to explore the effects on outcomes related to fall risk or safety aspects.

5. Conclusion

Walking while using a mobile phone has become a normal daily activity in today's society. Although the participants tested in this study were healthy young adults, we found the impact of mobile phone usage on gait variables differed according to the tasks. Modification of gait variables indicates the adjustment mechanism of the body when vision and attention are distracted by the tasks, which produced changes in gait parameters which could be considered as hazardous. However, this study was conducted in a controlled environment, and further studies should focus on more environmentally valid scenarios in different age groups.

Ethical statement

All participants were informed about the study details and asked to sign the informed consent approved by the Institutional Review Board (COA no. MU-CIRB 2019/015.2501).

Authors' contributions

1. Sunee Bovonsunthonchai: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft, Writing – review & editing.
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Declaration of competing interest

The authors report that they have no conflicts of interest.

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